could probably be selected which would flower at that latitude, and yet remain vegetative in the south of England. The flowering and vegetative limits of such a strain would be an integral part of its description.

The farther north the strain is to be used for pasture, the more difficult it will be to produce a non-flowering strain, since there will be fewer areas suitable for seed production. To obtain a strain which would remain vegetative everywhere in Britain, for example, seed would have to be grown on a commercial scale at latitudes above 60° N., probably in Scandinavia.

Although the biochemical basis of the photoperiodic response is not yet fully understood, it seems probable that in the future it will be possible to induce flowering in unfavourable photoperiods by suitable chemical treatment, thereby removing the main difficulty of seed production in non-flowering strains.

In conclusion, it seems clear that the production of non-flowering strains is now technically possible, but their economic use in farming practice will depend largely on the cost of seed production. It is suggested that the development and testing of such non-flowering strains deserve serious consideration.

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RADIOMETRIC AND GEOCHEMICAL SURVEY TECHNIQUES

AT the Geophysical Discussion of the Royal Astronomical Society held on January 31, Sir William Pugh introduced four invited speakers. He referred to the importance of atomic energy to our national economy and added that, although we had recently heard of the possibilities of the controlled release of thermonuclear energy, the present reactor programme was based upon uranium as the main fuel element. In view of this, and of the increased demands for rarer metals of value to our expanding industries, he stated that it was particularly appropriate to discuss radiometric and geochemical methods of prospecting at this time.

Mr. S. H. U. Bowie, in opening the session, recalled that prior to the Second World War only two mines, namely, Shinkolobwe in the Belgian Congo and Eldorado in Arctic Canada, produced significant tonnages of uranium ore; but, as a result of the intensive search during the past decade, more than 300 mines were now in production. Most of the discoveries had been made by the sound application of geological knowledge aided by instruments capable of detecting and measuring the gamma radiations from near-surface mineral occurrences. Both Geiger–Müller and scintillation counters are used in prospecting, and a variety of different instruments had been designed for specific purposes. The choice of a suitable instrument depends largely on the degree of reproducibility sought. If no allowances are made for terrain factors such as local topography, absorption of gamma photons by soil cover, or disequilibrium between uranium and its daughter elements due to weathering, a high statistical accuracy in the measurement of count-rate is unnecessary. Thus, a light-weight ratemeter, which averages the pulse-rate over a short period of time and has a count-rate of one or two pulses per second over flat-lying bedrock of a grade equivalent to 0·001 per cent equivalent U_3O_8, is adequate for preliminary prospecting purposes. More sensitive instruments are necessary for use by geologists in the detailed gridding of an area of anomalous radioactivity. In car-borne and airborne surveys, where the average radioactivity over intervals of traverse is recorded, scintillation counters of high sensitivity are necessary. For example, to obtain a count-rate of an accuracy of 10 per cent over 50-ft. intervals of traverse at a speed of 30 m.p.h., the count-rate of the instrument would have to be about 85 pulses per second over the same low-grade bedrock.

Airborne ratemeters designed by the Atomic Energy Research Establishment have single or triple thallium-activated sodium iodide crystals each 4⅝ in. in diameter and 1 in. thick coupled optically to a photomultiplier tube. Flight altitude and lane widths are dependent on the geology of the terrain to be surveyed, but two general techniques have been evolved. In one, flying is undertaken at an altitude of 500 ft. and at lane-widths of a quarter of a mile; in the other, the altitude is usually between 200 and 300 ft. and the lane-widths reduced accordingly.

Mr. Bowie concluded by saying that because of the ease with which uranium and thorium can be detected by geophysical means, geochemical techniques were not so important in the search for uranium as in the search for base metals. However, because of the high degree of mobility of the uranyl ion $(UO_2)^{2+}$ in solution, the detection of uranium in run-off water, particularly in river basins draining mountainous or forested country, was a valuable aid in the delineation of favourable areas.

Dr. J. S. Webb, who followed, said that geochemical methods of mineral exploration are based on the premise that diagnostic disturbances in the normal distribution pattern of chemical elements may exist in accessible material in the vicinity of concealed ore deposits. Such geochemical anomalies result from the natural dispersion of elements from the site of the parent deposit and are commonly sought by the, systematic sampling and analysis of rock, soil, vegetation, stream water and stream alluvium.

Geochemical dispersion patterns are subdivided into two genetic categories, namely, *primary dispersions* formed in depth at the time of mineralization, and *secondary dispersions*, which are usually formed in the zone of weathering. Primary dispersion patterns may occur as regional variations in the trace element content of rocks and minerals associated with metallogenic provinces, aureoles of impregnation in the wall-rocks surrounding individual deposits, or 'leakage' dispersions of trace metals in the channel-ways followed by mineralizing solutions. In all cases, the primary dispersion is genetically related to the ore-forming processes. The interpretation of the geochemical anomalies in terms of the location of possible associated deposits is often difficult and is dependent on the understanding of the local geology. Secondary dispersions, on the other hand, are usually associated with the weathering cycle, and although the dispersion processes are complex, considerable progress has been made in the development and application of techniques having a proved practical value in prospecting. This is particularly true of geochemical soil surveys in areas of residual overburden, where the methods have been successfully used for detecting the presence of sub-outcropping deposits of copper, nickel, arsenic, gold, antimony, chromium, tin, tungsten, molybdenum and other metals.

At times, positive results have been obtained where copper, lead and zinc mineralizations have been concealed by transported glacial cover up to some tens of feet thick. Here, the metals have had the opportunity of migrating upwards into the overlying material by diffusion and other processes, including the growth of vegetation which has extracted the ore metals as part of its nutrient uptake. Although the systematic analysis of the plants themselves has been employed on occasions, it is normally found more practicable to sample the underlying soil wherein metal has accumulated over generations in the biogeochemical cycle. Geochemical soil and vegetation anomalies are usually restricted to the immediate vicinity of the parent mineral deposit, but abnormal concentrations of metal may sometimes be detected in the surface drainage system up to several miles downstream from mineralization. Where such geochemical dispersion does exist, the systematic sampling of stream water or alluvium may constitute a useful aid in the rapid mineral reconnaissance of comparatively large areas. Sampling and analysis of stream alluvium for metals extractable at normal temperatures have given particularly encouraging results in reconnaissance for copper and base metal deposits.

The practical application of geochemical methods has been made possible only by the development of extremely rapid, simple tests and there are now trace analytical techniques for a wide range of metals capable of being performed with adequate accuracy by semi-skilled personnel. For the most part, these tests are simplified versions of classical colorimetric and chromatographic methods, although spectrographic, fluorimetric and other procedures may be utilized for particular problems.

Current research is active and aimed at broadening the scope of existing methods, extending knowledge of dispersion processes, investigating the regional approach to comprehensive geochemical reconnaissance and developing appropriate analytical techniques. Progress in the application of geochemical techniques indicates that, when used in conjunction with geological, geophysical and other sources of information, they will play an increasingly greater part in modern mineral exploration.

Mr. J. E. T. Horne next spoke on the determination of the age of radioactive mineralization and the importance of this in the search for further deposits. Knowledge of the age relationships between a mineralization, its enclosing sediments, and any igneous activity in the area could give, in many instances, a clearer indication of where to look for further occurrences. Such information was also valuable in understanding the genesis of ores, particularly in deciding between epigenetic and syngenetic origins. An example of a detailed age study that had led to practical results was the work of the United States Geological Survey on the uranium mineralization of the Colorado Plateau. There, field evidence had suggested a mineralization penecontemporaneous with the Triassic and Jurassic sediments, but analysis of more than fifty samples pointed to a late Cretaceous or early Tertiary age. This conclusion assisted in guiding a most successful prospecting and drilling programme.

Mr. Horne outlined the principles of dating uranium and thorium minerals from the four ratios lead-206/uranium, lead-207/uranium, lead-208/thorium and lead-207/lead-206, and discussed some of the factors responsible for the frequent lack of agreement in the derived ages. Formerly, the fact that lead/lead ages are commonly higher than the lead/uranium ages was attributed to the loss by diffusion of radon generated in the uranium-238 series, but laboratory measurements had failed to substantiate such loss in most cases. Lead derived from uranium and thorium before the deposition of a radioactive mineral and incorporated in it at the time of formation would seriously affect the apparent ages, and there was good evidence that such original radiogenic lead is present in some ore deposits. In this case, not only did all the apparent ages differ from one another, but also they were all too high. A third major cause of discrepancy was the loss of lead, either recently by leaching or earlier by solid diffusion. It was interesting that leaching experiments on some materials had effected a differential loss of lead-208 with respect to the other lead isotopes, indicating a difference in the distribution of uranium and thorium in the mineral. Finally, age discrepancies might arise from the loss of uranium or thorium and it was imperative to minimize this effect by obtaining the freshest possible material.

Age determination was not simple, but neither should it be dismissed as thoroughly untrustworthy. Some deposits were much more difficult to date than others ; these latter required the analysis of a comprehensive set of carefully selected samples, supported by meticulous observations in the field and mineralogical laboratory. Processes postulated to account for discrepancies must be established beyond reasonable doubt by independent evidence.

The last of the four principal speakers, Dr. W. Bullerwell, approached radiometric methods in borehole logging by discussing geophysical logs in general. He indicated, with examples from a deep boring for coal, how such records assist where core-recovery is poor and how geophysical marker horizons can help correlation between adjacent uncored boreholes. He stressed the importance of obtaining physical data on the properties of rocks from measurements made *in situ*, as the information so obtained could be applied in interpreting surface geophysical surveys. The continuous nature of the records also facilitates sampling and the averaging or integration of physical properties over a column of strata.

Just as classical studies first concentrated on natural radioactivity and later turned to activation methods, so borehole measurements of natural gamma radiation were followed by neutron techniques. For natural radiation measurements, ionization chambers, Geiger counters and scintillation counters have been used. The latter have a shorter 'active length' and this gives improved discrimination of thin beds. A relatively recent development is the scintillation spectrometer, which is capable of differentiating between the various energy-levels of incoming gamma rays. Since different elements are associated with gamma rays of differing energies, it becomes possible, in some instances, to obtain an indication of the nature of the nuclides responsible for the radioactivity by studying the pulse height distribution.

In neutron methods a neutron source is lowered into the borehole, followed by a detector. Neutrons will be captured by nuclei of the atoms that make up the surrounding rock, and the gamma rays emitted during these reactions can be recorded on a gamma detector. Similarly, if a neutron detector is used the distribution of neutrons in the borehole can be studied. Neutron sources commonly used, for example, radium–beryllium, also emit gamma rays, and it is necessary to shield the detector from the source in both neutron–neutron and neutron–gamma methods. Compton scattering and natural activity of the formation add complications. In gamma–gamma logging, which combines a gamma source and gamma radiation detector, scattered radiation, however, provides information related to formation density. Neutrons lose most of their energy in collisions with hydrogen, and as this element is abundant in both water and oil, neutron logs are important for porosity studies in oil exploration. In mentioning the combination of a neutron source with a scintillation spectrometer as detector, Dr. Bullerwell said that this would seem to offer the possibility of obtaining geochemical data by a geophysical method. A miniature Van de Graaff particle accelerator, 3 in. in diameter, 47 in. long and generating 200,000 V., has been used to produce an intense beam of neutrons during borehole experiments in the United States.

Radiometric logging methods have been applied in widely differing fields. Applications to detailed studies of radioactive ore-deposits are usually quite direct and closely controlled by assayed samples. Quantitative comparisons between sedimentary formations in oil-wells or deep structural boreholes, however, are complicated by varying conditions of observations. Calibration of instruments provides little difficulty, but ancillary data must be recorded to permit adequate correction for variations in borehole-diameter, mud-density, cement collars and thickness of casing. In concluding, Dr. Bullerwell stressed that these methods provide basic geophysical information, and he expressed the hope that should the proposal to drill a deep borehole to explore the Mohorovičić discontinuity come to fruition, then the opportunity to obtain a comprehensive series of geophysical logs should not be overlooked.

The chairman closed the meeting after a short informal discussion in which several speakers took part.

S. H. U. Bowie

CLIMATE, VEGETATION AND LAND UTILIZATION IN THE HUMID TROPICS

At the Ninth Pacific Science Congress, which was held at Bangkok, Thailand, during November 18–December 9, two days were devoted to a symposium on climate, vegetation and land utilization in the humid tropics, in which some eleven speakers dealt with different aspects of these closely related subjects. In addition to papers read by their authors, a few papers were read on behalf of contributors who were not present, and some invited guests, including one of the present writers (P. W. R.), who did not prepare papers, were asked to contribute to the discussions. The convener was Dr. F. R. Fosberg (Pacific Vegetation Project, Washington, D.C.), and the symposium was organized, and its proceedings will be published, with the financial support of Unesco. As so often happens, the time allotted for general discussion proved insufficient; nevertheless, a valuable opportunity was provided for an exchange of ideas between workers in different disciplines which do not come often enough into contact.

At the outset there was the question of definition: What do we mean by the tropics in general and by the humid tropics in particular? Broadly, as Dr. Fosberg said in his opening remarks, the two belts of trade-winds blowing towards the equator and the shifting belt of calms or doldrums are of greatest importance in defining these regions. Dr. David I. Blumenstock (Hawaii), who contributed a paper on the characteristics and distribution of tropical climates, expanded this by reminding the Congress of the special significance of weather or circulation regions, such as the monsoon region and, perhaps surprisingly, the hurricane areas; he regarded the tropical climatic realm as best defined as the region within which the temperature of the coldest month in the lowlands averages at least 64·4° F. (18° C.), with the included upland and mountain areas. In this sense the lowland humid tropics are the frost-free areas of the world, where the unique features are in the illumination and radiation regimes rather than in that of insolation. Dr. Blumenstock considered that radiation is a more important factor than previously believed. In regard to temperature he emphasized the importance of extremes; in regard to moisture, the significance of dew and the variability of rain through the year.

Dr. C. G. G. J. van Steenis (Leyden) and Dr. Carl Troll (Bonn) dealt, respectively, with the lowland and the mountain vegetation of the tropics. In the course of a very comprehensive review of tropical-